AMENDMENTS TO THE SPECIFICATION

Pages 1-3, paragraphs [0002] - [0009]:

[0002] As a device for detecting an abnormality of a rotating body, for example, a tire, the internal pressure abnormality alarming device is known~~,~~ which alerts the driver by means of an alarm when the internal pressure of the tire becomes lower than a given value. The device is designed to measure the internal pressure by means of an internal pressure sensor attached to a wheel of a tire, and to give an alarm when the internal pressure becomes lower than the given value.

[0003] However, ~~by means of~~ this type of internal pressure abnormality alarming device~~, it~~ can't detect a trouble caused by [[a]] any factor except a drop of the internal pressure. As ~~an example~~ examples of such [[a]] trouble, there ~~is~~ are a separation ~~occurred~~ occurring between a tread and a belting, between ~~codes~~ cords which constitute the belt, and between a side rubber and a carcass ply, or a breaking of a ply cord or a belting cord, or a chunk out of a tread rubber (wherein, for example, the block land portion arranged on a tread is picked off). If a car continues running ~~with~~ when these tire troubles occur ~~occurred~~, it may cause a sudden tire burst, so that it may be incapable of running anymore, and in addition it may cause a big accident.

[0004] As a system for detecting a trouble except the trouble of such an internal pressure, a system for detecting an abnormality of the rotating body (for example, Japanese Patent Laid-Open Publication No. 2003-80912 ~~No.2003-80912~~) which detects an abnormality of a tire by measuring the data of vibration and sound of the tire, and ~~compare~~ compares it with those of normal time measured previously, is known. Even with this type of detecting system of abnormality of the rotating body, it can detect the abnormality of the tire in a sufficient level, but

the device for detecting the abnormality of the rotating body with a simple configuration and an excellent performance was required in recent years.

[0005] An object of the present invention is to provide a device and method for detecting an abnormality of the rotating body, which can prevent an accident from occurring by detecting the tire burst or a separation of the tread of the rotating body, in particular, a tire, in an early stage.

[0006] According to the invention, the device for detecting an abnormality of a rotating body is characterized in that the improvement comprises: means for measuring various physical quantities of the rotating body in rotation; means for extracting a signal which is synchronized with the rotation of the rotating body from the data measured by the measuring means; means for determining a condition of the rotating body from the signal extracted by the extracting means; and abnormality warning means for giving a warning of an abnormality when the determining means determine that the condition of the rotating body is abnormal; wherein the extracting means comprise an adaptive digital filter in which the device extracts a signal synchronized with the rotation and picks out a signal having no correlation with the rotation by means of a data measured by the measuring means and a signal synchronized with the rotation extracted by the extracting means, and adapts the adaptive digital filter by means of the thus picked out signal having no correlation with the rotation.

[0007] In a preferred example of a device for detecting an abnormality of a rotating body according to the invention, the various physical ~~quantities~~ qualities of a rotating body measured by the measuring means have correlation with vibration, sound, rotating speed, or rotation; the delayed data of the rotation information data measured by the measuring means is used for extracting a signal synchronized with the rotation; the delay time of the rotation information data

is a time corresponding to one rotation of the rotating body; the delay circuit to make data delay is provided on a signal line between an input portion of rotation information data from the measuring means and an adaptive digital filter; and the delay circuit to make data delay is provided on a signal line between the input portion of rotation information data from the measuring means and a comparator for picking out the signal having no correlation with the rotation.

[0008] In addition, in another preferred example of a device for detecting an abnormality of the rotating body according to the invention, an order component which is generated by calculating the rotational cycle by means of the rotation information data provided by the measuring means is used in extracting a signal synchronized with the rotation in the extracting means; and the order component generation circuit is provided on a signal line between an input portion of the rotation information data from the measuring means and the adaptive digital filter.

[0009] Furthermore, in the other preferred example of a device for detecting the abnormality of the rotating body according to the invention, in extracting a signal synchronized with the rotation in the extracting means, the data measured by the measuring means is variably sampled in accordance with the rotation information data provided by the measuring means to make an apparent cycle constant, and the variable sampling circuit is provided on an input portion of the rotation information data from the measuring means for performing the variable sampling.

Page 4, paragraph [0011]:

[0011]

~~[Fig.1] Fig.1 is a figure to explain~~ Fig. 1 is an example of a device for detecting an abnormality of a rotating body according to the invention.

~~[Fig.2] Fig.2~~ Fig. 2 is a block diagram ~~to explain~~ explaining an example of an extracting means according to the invention.

~~[Fig.3] Fig.3~~ Fig. 3 is a block diagram ~~to explain~~ of another example of an extracting means according to the invention.

~~[Fig.4] Figs.4 (a) and (b) are figures to~~ Figs. 4(a) and 4(b) show the state of a vehicle when measuring the actual waveform.

~~[Fig.5] Fig.5 is a figure to show one example~~ Fig. 5 shows examples of input signal X(i) ~~X (i)~~ output signal Y(i) ~~Y (i)~~, error signal E(i) ~~E (i)~~ of each tire [[in]] on a good road.

~~[Fig.6] Fig.6 is a figure to show one example~~ Fig. 6 shows examples of input signal X(i) ~~X (i)~~, output signal Y(i) ~~Y (i)~~, error signal E(i) ~~E (i)~~ of each tire [[in]] on a rough road.

~~[Fig.7] Fig.7~~ Fig. 7 is a block diagram ~~to explain a~~ explaining still another example of an extracting means according to the invention.

~~[Fig.8] Fig.8 is a figure to show one examples~~ Fig. 8 shows examples of input signal X(i) ~~X (i)~~, output signal Y(i) ~~Y (i)~~ (here, showing 3 output signals), error signal E(i) ~~E (i)~~ (here, showing 3 error signals) in the extracting means of Fig. 7 ~~Fig.7~~.

~~[Fig.9] Fig.9~~ Fig. 9 is a block diagram ~~to explain a~~ explaining still another example of an extracting means according to the invention.

~~[Fig.10] Figs.10 (a) and (b)~~ Figs. 10(a) and 10(b) are block diagrams ~~to explain a~~ explaining still other example of an extracting means according to the invention.

Pages 4-7, paragraphs [0012] - [0019]:

[0012] ~~Fig.1 is a figure to explain~~ Fig. 1 is an example of a device for detecting an abnormality of a rotating body according to the invention. Even though the explanation of the invention in the example of ~~the Fig.1~~ Fig. 1 is based on tires installed on a vehicle as rotating bodies, it is clear that the invention is also able to be adapted to ~~another~~ other rotating bodies except [[tire]] tires as long as it is intended to detect the abnormality of the rotating body [[in]] during rotation.

[0013] In an example shown in Fig. 1, ~~Fig.1, references 1 are~~ reference 1 denotes tires used as rotating bodies, ~~references 2 are~~ reference 2 denotes sensors mounted on each tire for measuring the vibration or sound of [[those]] the rotating bodies, reference 3 is a central processing unit for detecting the abnormality of tires 1 by signals measured by respective sensors 2. The device for detecting an abnormality of a rotating body according to the invention comprises: measuring means 11 for measuring physical quantities such as vibrations or sounds by means of respective sensors 2; extracting means 21 for extracting a signal which is synchronized with the rotations of tires 1 from the data measured by measuring means 11; determining means 31 for determining conditions of the tires 1 from the signal extracted by the extracting means 21; and abnormality warning means 41 for giving a warning of abnormality to a driver when the determining means 31 determine the conditions of a tire 1 [[is]] are abnormal.

[0014] The measuring means 11 measures sounds or vibrations around tires 1 by means of sensors 2, or a signal of rotating speed of, for example, ABS (no need [[of]] for sensors 2), and

[[send]] sends those measured data to the extracting means 21 in a form of digital signal. In measuring a sound, a sensor such as microphone is used as sensor 2. In measuring a vibration, a sensor such as accelerometer, speedometer, or displacement meter is used as sensor 2. In addition, when ABS (the Anti-lock Brake System) is installed on the vehicle, the rotating speed signal of the ABS can be used. In this case, there is no need for providing a sensor 2, and the device can be done with simple configuration. Without using ABS, the rotating speed signal can be used by measuring a rotating speed or a signal synchronized with the rotation of tire, by means of ~~another~~ other methods.

[0015] In extracting means 21, it is preferred to extract a cycle component synchronized with the rotation of the tire 1 by means of the adaptive digital filter. Namely, as one example of configuration of the extracting means 21 shown in Fig. 2 ~~Fig.2~~, in the extracting means 21, digital signal X(i) measured by the measuring means 11 is inputted to the extracting means 21, the input signal and delay signal of the input signal delayed by a delay circuit 22 are operated in the adaptive digital filter in real time, [[and]] a signal correlated with the cycle of the tire 1 is outputted as a output signal Y(i), the input signal is sent to the adaptive digital filter through a comparator 24 as a reference signal R(i), and the delay signal is sent to the adaptive digital filter directly. Therefore, the output signal Y(i) can be given as a signal which [[have]] has a correlation with the rotation of the tire 1, in other words, a cyclical signal. The given output signal Y(i) is inputted to the determining means 31.

[0016] Delay time generated in the delay circuit 22 is preferably shorter than the time corresponding to one cycle of the tire 1. However, if the time is longer than two cycles, or is a little bit shorter or longer than [[the]] one cycle, there is no problem in giving a cycle component

synchronized with the rotation due to characteristics of the adaptive digital filter 23. In addition, in [[a]] case the cyclical time of the tire 1 differs according to the rotating speed (running speed of the vehicle), it is able to give a cycle component by setting sampling frequency and tap length of the adaptive digital filter 23 well. Moreover, it can be done by setting the delay time in advance for ~~tree~~ three stages[[,]]: low speed, middle speed, and high speed, and changing the delay time of the delay circuit 22 in ~~tree~~ three stages based on the speed of the vehicle. Of course, it can be done by measuring the speed of a vehicle all the time, and changing the delay time of the delay circuit 22 in real time in accordance with the measured speed.

[0017] The adaptive digital filter 23 can be of a known conventional constitution. In the example shown in Fig. 2 ~~Fig.2~~, reference signal R(i) consisted of the digital data X(i) measured by the measuring means 11, and the output signal Y(i) from the adaptive digital filter [[are]] is calculated in the comparator 24 and the difference of those are calculated, and it is given as error signal E(i). Therefore, error signal E(i) can be given as a signal unrelated to a rotation of tire 1, and as a random signal related to the surface of the road or the body of the vehicle itself. And the adaptive digital filter 23 is optimized by changing the coefficient of it dynamically in response to the error signal E(i) fed back to a coefficient change portion of the adaptive digital filter 23.

[0018] For the method to optimize the filter 23 by feeding back the error signal E(i) to the coefficient change portion of the adaptive digital filter 23, adaptive methods known as a filter coefficient updating algorithm can be used, such as LMS (Least Mean Square) method, Newton method, or Steepest descent method. In addition, the following methods also can be used as the adaptive algorithm preferably; Complex Least Mean Square Algorithm, Normalized Least Mean

Square Algorithm, Projection Algorithm, Simple Hyper stable Adaptive Recursive Filter Algorithm, Recursive Least Square Algorithm, Fast Least Mean Square Algorithm, Adaptive Filter using Discrete Cosine Transform, Single Frequency Adaptive Notch Filter, Neural Network, and Genetic Algorithm.

[0019] For an example of the extracting means 21, there is another example different from the example in which the delay circuit 22 is provided between the input portion of the digital signal X(i) and the adaptive digital filter 23 as shown in Fig. 2 ~~the Fig.2~~. Such example can be used in which the delay circuit 22 is provided between the input portion of the digital signal X(i) from the measuring means 11 and the comparator 24 for delaying the reference signal R(i) as shown in Fig. 3 ~~the Fig.3~~, so that the same functions and effects to the case of the invention of Fig. 2 ~~the Fig.2~~ can be obtained.

Pages 8-12, paragraphs [0024] - [0032]:

[0024] The actual waveform of the abnormality detecting device of rotating body according to the present invention is subsequently described. In a vehicle which comprises front ~~wheel(left)~~ wheel (left) 1-1, front ~~wheel(right)~~ wheel (right) 1-2, rear ~~wheel(left)~~ wheel (left) 1-3, and rear wheel (right) ~~wheel(right)~~ 1-4, as shown in Figs. 4(a) and 4(b) ~~Figs.4 (a) and (b)~~, a burst portion 51 is assumed to be generated in a shoulder portion of the front ~~wheel(left)~~ wheel (left) 1-1. The signal waveforms of the input signal X(i), output signal Y(i), and error signal E(i) of each tire were measured in early stage of outbreaking of the burst portion 51~~(the~~ (the whole tire will be damaged in late stage) by measuring a vibrational acceleration using a sensor arranged on a knuckle portion of the tire for two cases running on good road and rough road.

[0025] ~~Fig.5 is a figure to show~~ Fig. 5 shows examples of input signal X(i) ~~X (i)~~, output signal Y(i) ~~Y (i)~~, and error signal E(i) ~~E (i)~~ of each tire in good road, and ~~Fig.6 is a figure to show~~ Fig. 6 shows examples of input signal X(i) ~~X (i)~~, output signal Y(i) ~~Y (i)~~, and error signal E(i) ~~E (i)~~ of each tire in rough road. As seen from ~~the two figures Fig.5~~ Figs. 5 and 6 ~~Fig.6~~, even though a signal which has correlation with the rotation of the tire (signal occurred by the burst portion 51) is mixed with a signal which has no correlation with the rotation of the tire (signal occurred by the property of the road such as irregularity) as input signal X(i), the cyclical signal which shows the outbreaking of the burst is seen only in the output signal Y(i) of the front ~~wheel(left)~~ wheel (left) 1-1 which has the burst portion 51, and there are no signals in the output signals Y(i) of tire which have no abnormality, so that the device can determine the outbreaking of the burst correctly.

[0026] In addition, according to the invention, as shown by Fig. 6 ~~Fig.6~~, even though the input signal X(i) comprises a desired signal which has correlation with the rotation of tire (signal occurred by the burst portion 51) and a signal which has bigger amplitude of vibration than desired signal (signal occurred by the rough road), the cyclical signal which shows the outbreaking of the burst is seen only in the output signal Y(i) of the front wheel(left) wheel (left) 1-1 which has the burst portion 51 and the rest of output signals Y(i) of normal wheels 1-2 to 1-4 show no signal, so that the device can determine the outbreaking of the burst correctly as the case running on a good road. In addition, in the examples shown in ~~Fig.5~~ Figs. 5 and 6 ~~Fig.6~~, the error signal E(i) is a changeable signal, which change alters the coefficient of the adaptive digital filter 23, and the characteristic of the adaptive digital filter 23 is changed based on the alternation of the coefficient of the filter.

[0027] The device for detecting an abnormality of a rotating body of the present invention described above is only ~~a~~ an example, and its configuration is not limited to the described one. As another configuration of an extracting means different from those shown in Figs. 2 ~~Figs.2~~ and 3, the following configuration can be used.

[0028] Fig. 7 is a block diagram to explain an example of another extracting means according to the invention. In an example shown in Fig. 7 ~~Fig.7~~, the same members as those of the examples of Figs. 2 ~~Figs.2~~ and 3 are denoted by the same ~~referring~~ reference numerals as those of Figs. 2 ~~Fig.2~~ and 3, and explanations for these members are omitted. When a signal not synchronized with the rotation of the tire (a signal generated by such as property of the road or vehicle body) is larger than a signal synchronized with the rotation of tire, or a signal synchronized with the rotation of tire is small, as shown in Fig. 7 ~~Fig.7~~, the device can extract the synchronized signal more accurately by using plural adaptive digital filters 23 connected in series (digital filters 23-1 to 23-3 in a shown example) than extract by using one digital filter 23. Namely, in an example shown in Fig. 7 ~~Fig.7~~, the accuracy of the extracting means is improved by operating the following process repeatedly[[;]]: input a signal of vibration, sound, and rotating speed as [[a]] an input signal X(i), and input [[a]] an output signal Y1(i) of first filter 23-1 (ADF 1) to the second filter 23-2 (ADF 2). In addition, there are no limitations on the number of connected filters.

[0029] Fig. 8 ~~is a figure to show one~~ shows examples of input signal X(i) ~~X (i)~~, output signal Y(i) ~~Y (i)~~, error signal E(i) ~~E (i)~~ in the extracting ~~mean~~ means of Fig. 7. Here, output signal Y(i) ~~Y (i)~~ is output signal 3, and error signal E(i) ~~E (i)~~ is error signal 3. As seen from Fig. 8 ~~the Fig.8~~,

the extracting means can extract a defect more accurately in third output signal Y3(i)~~Y3 (i)~~ than in second output signal Y2(i), in second output signal Y2(i) than in first output signal Y1(i).

[0030] Fig. 9 is a block diagram ~~to explain a~~ explaining still another example of an extracting ~~mean~~ means according to the invention. In an example shown in Fig. 9 ~~Fig.9~~, the same members as those in the example of ~~Figs.2~~ Figs. 2 and 3 are denoted by the same ~~referring~~ reference numerals, and explanations for these members are omitted. As mentioned above, it can extract all cyclical ~~signal~~ signals by means of some logic of adaptive digital filter (such as connecting plural filters)[[,]]; however, besides a signal synchronized with the rotation ~~occurred~~ occurring by the abnormality of the rotating body, it also extracts the signal ~~occurred~~ occurring by the disturbance when it is synchronized with the rotation. Thus, as shown in Fig. 9 ~~Fig.9~~, an order component generation circuit 25 is provided between an input portion of rotating signal P(i) which is a rotational data from the measuring means 11 and the adaptive digital filter 23, and an order component used in extracting process is generated from the rotating data of rotating body (for example, a rotating data from wheel rotating sensor in case of vehicle) in the circuit, so that only a desired signal is to be extracted by applying the order component to the adaptive digital filter 23. The thus generated order component is an arbitrary order number and not limited about the number to be generated. In addition, there are no limitations on the number of filters.

[0031] Figs. ~~10 (a) and (b)~~ 10(a) and 10(b) are block diagrams to explain the other example of an extracting ~~mean~~ means according to the invention. In the examples shown in Figs. 10(a) and 10(b) ~~Figs.10 (a) and (b)~~, the same members as those in the examples of ~~Figs.2~~ and 3 are denoted by the same ~~referring~~ reference numerals, and explanations for these members are omitted. When the rotating speed of the rotating body (a speed of a vehicle in case of vehicle) is changed

in examples of Figs. 2 ~~Figs.2~~, 3, 7, and 9, the adaptive digital filter 23 may not be able to be applied satisfactorily in some cases [[case]]. Thus, as shown in ~~Figs.10 (a) and (b)~~, a variable sampling circuit 26 is provided at an input portion from the measuring means, the sampling is to be variable by using a rotating data of rotating body (for example, an [[a]] ABS wheel speed signal in case of a vehicle) for making the data of input signal to be a canonicalized rotating speed (cycle), and a logic to operate the process in the adaptive digital filter 23 in which the cycle appears to be constant is used, so that the filter can be satisfactorily respond to the change of the speed of the rotating body.

[0032] Plural units of the inventions of Figs. 9, 10(a) and 10(b) ~~the Fig. 9 and Figs.10 (a) and (b)~~ may also be connected in series to be one unit. In this case, it can improve the sampling accuracy further. In addition, there showed examples in which the variable sampling circuit 26 is respectively provided to the extracting means of using the delay circuit 22 in Fig. 10(a) ~~Fig.10 (a)~~ and to the extracting means of using the order component generation circuit 25 in Fig. 10(b) ~~Fig.10 (b)~~, it is also effective to provide a variable sampling circuit to another example of an extracting means, such as an extracting means in which plural adaptive digital filters 23 are connected in series as shown in Fig. 7 ~~Fig.7~~. Even more particularly, in the example using the order component generation circuit 25 as shown in Fig. 10(b) ~~Fig.10 (b)~~, only a desired signal is extracted by generating order component from rotating speed data (cycle) normalized in the variable sampling circuit 26, and applying the thus extracted signal and input signal to the adaptive digital filter. Even more particularly, in an example shown in Fig. 10(a) ~~Fig.10 (a)~~, the delay circuit 22 is placed between [[the]] a variable sampling circuit 26 and the determining ~~mean~~

means 31[[,]]; however, it may be placed between the variable sampling circuit 26 and the adaptive digital filter 23.

Page 13, paragraph [0034]:

[0034] ~~As the~~ A device for detecting an abnormality of a rotating body according to the invention comprises[[,]]: measuring means for measuring the various physical quantities of the rotating body in rotation, extracting means for extracting the signal which is synchronized with the rotation of rotating body by the data measured by the measuring means, determining means for determining a condition of the rotating body from the signal extracted by the extracting means, and abnormality warning means for giving warning of abnormality when the determining means determine that the condition of the rotating body is abnormal[[,]]; it can detect an abnormality of the rotating body (it can be arrested as cyclical signal when the rotating body is rotating), in particular such as burst of tire, separation of tread, in early time, so that it can be applied to ~~the use to~~ prevent accidents caused by the abnormality of the rotating body.